Lisbon School of Economics & Management
Universidade de Lisboa

MASTER

MANAGEMENT AND INDUSTRIAL STRATEGY

MASTER´S FINAL WORK

DISSERTATION

THE IMPACT OF CLIMATE CHANGE AWARENESS INDEX ON PORTFOLIO RETURNS IN THE UNITED STATES IN THE LAST 20 YEARS

ISABEL ALMEIDA ROQUE

OCTOBER - 2024

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SUPERVISION:
ADRIANA CORNEA - MADEIRA

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GLOSSARY

ADF- Augmented Dickey-Fuller

AEWR- Average Equal Weighted Returns

AGW- Anthropogenic Global Warming

B2B- Business to Business

B2C- Business to Consumer

CCAI- Climate Change Awareness Index

CO2- Carbon Dioxide

FFR- Federal Funds Effective Rate

FRED- Federal Reserve Economic Data

GTU- Google Trends Uncertainty

HAC- Heteroskedasticity and Autocorrelation-Consistent

IP- Industrial Production

KPSS- Kwiatkowski–Phillips–Schmidt–Shin

UN- Unemployment Rate

ABSTRACT

This dissertation is the first attempt to create a new way to assess uncertainty and awareness regarding climate change using Google Trends.

Climate change is a global concern and has been the focus of many studies, as has its impact on the economy. The inspiration for this study was the work of Castelnuovo and Tran (2017) with the construction of a climate policy uncertainty index using Google Trends. The index is based on the assumption that Internet users search for information online when they are uncertain or interested. This work opened doors to the construction of new indexes for different countries.

In the first part of the dissertation, seventy seven words were chosen and three Climate Change Awareness Indexes were constructed with different benchmarks for the United States from January 2004 to June 2024.

In the second part it is analysed the impact of this Climate Change Awareness Index on the return of forty nine industry portfolios in the United States, from February 2004 to March 2024.

The results demonstrate a statistically significant contribution to the returns of industry portfolios influenced by the dynamics of the Climate Change Awareness Index. Most industries had a negative but slight impact on their immediate returns. The most relevant underlying factors are changes in consumer preferences, market exposure, increased operational and innovation costs, consumer proximity, regulatory pressure, among others.

KEYWORDS: Climate Change; Google Trends Index; Portfolio Returns.

JEL CODES: C22; C43; E44.

RESUMO

Esta dissertação é a primeira tentativa de criar uma nova forma de aceder à incerteza e à consciencialização sobre as alterações climáticas utilizando o Google Trends.

As alterações climáticas são uma preocupação global e têm sido o foco de muitos estudos, tal como o seu impacto na economia. A inspiração para este estudo foi o trabalho de Castelnuovo e Tran (2017) com a construção de um índice de incerteza da política climática com recurso ao Google Trends. O índice baseia-se no pressuposto de que os utilizadores de Internet procuram informação online quando estão inseguros ou interessados. Este trabalho abriu portas para a construção de novos índices e para diferentes países.

Na primeira parte da dissertação foram escolhidas setenta e sete palavras e construídos três Índice de Perceção de Alterações Climáticas com diferentes benchmarks para os Estados Unidos de janeiro de 2004 a junho de 2024.

Na segunda parte é analisado o impacto deste Índice de Perceção de Alterações Climáticas no retorno de quarenta e nove carteiras industriais nos Estados Unidos, de fevereiro 2004 a março de 2024.

Os resultados demonstram um contributo estatisticamente significativo para o retorno das carteiras industriais influenciadas pela dinâmica do Índice de Perceção de Alterações Climáticas. A maioria das indústrias teve um impacto negativo, mas ligeiro, no seu retorno imediato. Os fatores subjacentes mais relevantes são as alterações nas preferências dos consumidores, a exposição ao mercado, o aumento dos custos relacionados com os custos operacionais e de inovação, a proximidade do consumidor, a pressão regulamentar, entre outros.

PALAVRAS-CHAVE: Climate Change; Google Trends Index; Portfolio Returns.

JEL CODES: C22; C43; E44.

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I would also like to thank my boyfriend João and my friends, especially Joana, Udie and André for their constant motivation and encouragement.

Finally, I dedicate my thesis to my dear grandfather João, a geography and encyclopedia fanatic who I hold close to my heart.

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1. INTRODUCTION

This work constructs an index of Climate Change Awareness using Google Trends and analyses its impact on 49 industry portfolio returns in the United States. The index is based on the assumption that Internet users look for information online when they are unsure or interested (Castelnuovo and Tran, 2017). The level of frequency with which they search reflects their level of concern and interest.

The inspiration for this dissertation was the work of Castelnuovo and Tran (2017) with the construction of a Climate Policy Uncertainty Index, CCAI, for the United States and Australia using Google Trends. The authors also studied its contribution on unemployment dynamics in each country. There is a growing literature on the use of Google Trends to construct indices, but to the best of my knowledge a Climate Change Awareness Index using Google Trends has not yet been built.

For the construction process, keywords associated with uncertainty or awareness, frequently used in papers, articles, publications and tweets related to climate change were chosen. Once each word was tested individually, a list of 77 keywords was formed. An important assumption in Google Trends is the fact that only 5 words can be entered at a time, therefore, an aggregation process was necessary. This process follows the Castelnuovo and Tran (2017) method. Groups of keywords were formed and a benchmark was present in all groups in order to "de-link" the frequency of each keyword from the specific group that is searched with. Once all frequencies are de-linked, the Climate Change Awareness Index is formed. For the sake of robustness check, this process was done three times with three different benchmarks.

A multiple linear regression was then used to test the impact that CCAI has on portfolio returns of 49 industries in the United States. For portfolio returns data, Average Equal Weighted Returns (AEWR) of portfolios in the U.S. for 49 industries were extracted as monthly data from 2004 until 2024 from the Fama-French Data Library. To account for the state of the economy the control variables used were Industrial Production, Federal Funds Effective Rate and Unemployment Rate.

The estimation results indicate that the CCAI is statistically significant for 36 industries, namely, 10 industries are at 1% level, 17 industries are at 5% level and 9 industries at 10% level. From February 2004 until March 2024, the impact of CCAI was negative, ranging between -0.0156 and -0.0032. The non-significance of some industries was a surprise, such as “Agriculture” and “Petroleum and Natural Gas”. In contrast, the “Beer & Liquor” and “Printing and Publishing” industries showed the strongest results.

Industries more directly related and affected by factors such as changes in consumer preferences, exposure to the market, proximity to the consumer, regulatory pressure, among others, suffer a greater impact. Industries more vulnerable to physical and transition risk or industries with a reputation associated with problems that worsen climate change (e.g. deforestation and high carbon footprint) are also affected. The increase in costs related to production, design and innovation, for example new ways of production, new recycling programs, searching suppliers with eco-friendly practices, waste management, carbon tax and others, can increase operational costs and affect logistical efficiency. As a consequence, this factors can reduce profitability and returns.

This dissertation is organized as follows. Chapter 2 presents the literature review on the Google Trends Uncertainty and on the study of the climate change impact on financial markets. In Chapter 3, the steps for building the CCAI are described, as well as the data (the Google Trends data and the industry returns). Chapter 4 contains the results. The final chapter presents the conclusions.

2. LITERATURE REVIEW

Climate change has become one of the biggest global challenges, gaining more recognition, not only because of its environmental implications, but also social, political and economic implications it entails.

It is important to address climate risks as a variable of discussion and incorporate it in financial decisions to better address risks, future losses and to promote a more sustainable economy.

Understanding what climate change is and how it can influence the performance of multiple industries is crucial to better understand the drivers of financial returns.

This section is divided in three subsections. First, climate change is defined. Second, the use of Google Trends in literature is presented. Finally, some similar studies that analyse the impact of climate change in the stock returns are also presented.

2.1. What is Climate Change

According to World Meteorological Organization (WMO), only the changes in average weather patterns over an extended period define climate change.

For NASA it is stated “climate change is a long-term change in the average weather patterns that have come to define Earth’s local, regional and global climates”.

For the United Nations Framework Convention on Climate Change (UNFCC) it also defines that it is the changes in the global climate system but related directly or indirectly to human activities.

2.2. The use of Google Trends in Literature

Google Trends is commonly used by researchers in academic papers, as it measures the popularity of certain search terms on Google and has become an important analytic tool for researchers around the world, in different fields, as social sciences or medicine (Kam et al., 2019).

Austin et al. (2021), in an International Monetary Fund working paper, studied how data extracted from Google Trends could "develop high frequency indicators aligned to the statistical concepts, classifications and definitions used in producing official measures", reaching the conclusion that, during the early stage of COVID-19, through two indicators it was possible to predict the fall and recovery of the GDP of certain selected countries.

Vosen and Schmidt (2011), studied the use of Google Trends to create a new indicator for private consumption, by using 56 related terms, to use in forecasting private consumption. Compared to traditional performances using University of Michigan Consumer Sentiment Index and the Conference Board Consumer Confidence Index, the authors found that in "almost all conducted in-sample and out-of-sample forecasting experiments the Google indicator outperforms the survey-based indicators".

Yu et al. (2019), studied the use of Google Trends in online big data-driven oil consumption forecasting model. The authors found that "statistical tests show the Google trend of 'oil consumption' to be an effective predictor for oil consumption, in terms of both significant cointegration and Granger causality relationships with global oil consumption". Also, the authors found that the use of Google Trends significantly improves models that aim to predict the trends and values of oil consumption.

Rauf and Ahmed (2023), using the keywords data set from Gavriilidis (2021), created a Google Trends Climate Policy Index and further analysed its association with CO2 emissions for Pakistan. The authors concluded that "shock in climate uncertainty index is associated to CO2 emissions so that the availability of new uncertainty index aids researchers in their quest to understand the relationship not only between CO2 and climate uncertainty also other variables and climate uncertainty".

2.3. Similar studies that analyse the Impact of Climate Change on Stock Returns

Ouadghiri et al. (2021) considered the effect of public attention to climate change and pollution on returns on the U.S. sustainability stock indices versus conventional indices like the S&P 500 Index or FTSE USA. To access public attention of environmental risks, the authors used "(i) US media attention to climate change and pollution and (ii) the US Google Search Volume Index for these two keywords". They reached the conclusion that public attention to climate change and pollution has a positive effect on these sustainability stock indices and a negative effect on the conventional parent stock indices.

Fahmy (2022) studied the investor's awareness of climate risks, by assessing the connection between oil and technology stock prices and clean energy prices, between two different time periods, before and after the Paris Agreement. This studied concluded that the Paris Agreement and other climate-related events are differentiating the clean energy sector from the traditional energy market, as "the superiority of technology prices over oil price" is " driving the cyclical behaviour of clean energy assets".

Antoniuk and Leirvik (2021) found that "events related to climate change policy have significantly impacted returns". The Paris Agreement and events such as the Climategate in 2009 and the Fukushima nuclear disaster in 2011 "increased climate change awareness and favour toward policies to reducing the impact of climate change". For the utilities, transports and energy-intensive industries, there were increasing political and market risks related with the green transition of these sectors, which should be compensated and "events weakening climate change policy are associated with positive abnormal returns for the fossil energy sector".

The authors found as well, that "stock market investors are quick to adapt to new information related to climate change" and state that "policymakers should be aware of such events' impact on the stock market because the investors are likely to price in both climate risk and expectation about sectors' growth".

3. DATA AND METHODOLOGY

Google Trends is a free tool from Google Corporation that allows to monitor in real time what people are searching for in a specific geography and time period. It provides estimates of how often a keyword is typed in comparison to the total searches performed on Google Search. (Rauf and Ahmed, 2023). Google Trends normalizes and scales data between 0 and 100, where 100 represents the peak popularity of a search, allowing for trends in audience interest and public opinion to be detected (McLean et al. 2016). By reflecting people's interests and searches, Google Trends is useful for assessing climate change uncertainty and creating a climate change uncertainty index.

3.1. Index Construction

The model to construct a Google Trends index follows Castelnuovo and Tran (2017). In this paper, the authors used Google Trends to create an Economic Uncertainty Index for United States and Australia and studied its impact on unemployment in each country.

The construction of Google Trends Uncertainty (GTU) indices is based on the assumption that Internet users search for information online when they are uncertain. The frequency of searched topics reflects awareness and levels of uncertainty felt. When the level of uncertainty and awareness is high, searches for terms associated with uncertain future events are also high.

While validation of Internet data is not necessary when considering active public rather than general public (Mellon, 2013), the tool remains valuable for understanding changes and uncertainties in the public behaviour.

Since the country of focus in this paper is the United States of America, to construct the GTU climate change index, queries located in the United States of America are used, covering monthly data from the periods of January of 2004 to June of 2024, the maximum available length of time in Google Trends.

3.1.1. Keywords Selection

Keywords associated to climate change are needed to construct the index. Many papers used newspapers to construct a list of keywords, but for this paper the word "climate change" is searched online and the related keywords are observed and extracted. One example regarding the online search of climate change can be the article "*The Effects of Climate Change*" (NASA, 2024) where it is reported that "the severity of effects caused by climate change will depend on the path of future human activities. More greenhouse gas emissions will lead to more climate extremes and widespread damaging effects across our planet. However, those future effects depend on the total amount of carbon dioxide we emit". From this example, the words that are highlighted are "climate change", "greenhouse gas emissions", "human activities", "climate extremes", "damaging effects" and "carbon dioxide".

Also X (former twitter) has become a source of information and discussion since the general public also use social media for this purpose, meaning that X is used to spread climate change awareness (Cody et al., 2015).

Cody et al., (2015) analysed climate change sentiment on Twitter and found that "disaster" and "hurricane" are more frequently used in climate-related tweets.

Al-Saqaf and Berglez (2019) on the paper "How Do Social Media Users Link Different Types of Extreme Events to Climate Change?" stated that tweets about flooding were the most predominant topic in connection with climate change illustrating how extreme weather events drive significant spikes in online activity.

In Williams et al. (2015), more than 590 thousand tweets were collected related to climate change. The five hashtags used were #climate, #climatechange, #globalwarming, #agw and #climaterealists.

In the study by Effrosynidis, Sylaios and Arampatzis (2022), "Exploring climate change on Twitter using seven aspects: stance, sentiment, aggressiveness, temperature, gender, topics and disasters", they created a cloud of words based on tweets regarding different topics discuss about climate change. When discussing the importance of Human Intervention the most frequent words were "action", "fight" and "Paris agreement".

When regarding hashtags some frequent words are “#renewableenergy”, “#climatecrisis” and “#sustainability”.

Following this pattern of research and thinking, the words associated to climate change used in Google Trends to construct the CCAI are presented in Table I below:

TABLE I

LIST OF KEYWORDS USED IN GOOGLE TRENDS TO CONSTRUCTED THE CLIMATE CHANGE AWARENESS INDEX

1	AGW	27	Environmental impact	53	Natural disasters
2	Alternative energy	28	Environmental law	54	Nature degradation
3	Biodiversity loss	29	Environmental regulations	55	Nature loss
4	Carbon emissions	30	Extreme flooding	56	Nature risk
5	Carbon footprint	31	Extreme temperatures	57	Net-zero emissions
6	Carbon tax	32	Extreme weather events	58	Oil drilling
7	Clean energy	33	Flood	59	Ozone layer
8	Climate action	34	Fossil fuel consumption	60	Paris Agreement
9	Climate bill	35	Fossil fuel	61	Pollution
10	Climate change	36	Fuel efficiency	62	Precipitation
11	Climate crises	37	Gas emissions	63	Renewable energy
12	Climate finance	38	GHG emissions	64	Renewable sources
13	Climate policy	39	Global climate change	65	Renewable
14	Climate rally	40	Global warming	66	Sea level rise
15	Climate related risks	41	Green energy	67	Severe weather
16	Climate risk	42	Green finance	68	Storms
17	Climate sensitivity	43	Green transition	69	Sustainability
18	Climate variability	44	Greenhouse effect	70	Sustainable finance
19	Climate-related events	45	Greenhouse gas emissions	71	Sustainable
20	CO2	46	Heat waves	72	Temperature increases
21	Decarbonization	47	Hurricane	73	Temperature shocks
22	Deforestation	48	Infrastructure damage	74	Tornados
23	Droughts	49	Loss of biodiversity	75	Toxic waste
24	Endangered species	50	Low-carbon economy	76	Warming climate
25	Energy efficiency	51	Low-carbon	77	Wildfire
26	Environmental degradation	52	Melting ice caps		

3.1.2. Aggregation Process

By doing research on Google Trends, the frequency of the searched term in comparison to the searched total volume is provided. Google Trends divides each data point $R_{i,j,m,c}$ - which is, the frequency of the search word "i" in a specific group of searched words "j" during a certain month "m" in a given country "c". This mentioned data point is then divided by the total amount of searches "T" in the same month and country. The formula is the following:

(1) $$S_{i,j,m,c} = \frac{R_{i,j,m,c}}{T_{m,c}}.$$

The numbers that come as result from the previous formula are then re-scaled to range between 0 and 100, being 100 the maximum, meaning that the given searched term "i" would be the most searched term out of the group "j".

The relative frequency of a searched term i in a group of searched terms j is represented by:

(2) $$FI_{ij} = 100 \times \left(\frac{S_{i,j}}{\max(S_{i,j})}\right).$$

To aggregate the data, it is needed to choose a benchmark term, since Google Trends only allows the input of a maximum of 5 keywords at a time. To do the aggregation of data, first, five search terms were chosen randomly and entered into Google Trends and one term, associated to the frequency $FI^{*}_{y,m}$, is chosen to be the benchmark.

Since there are 77 keywords used to construct the climate change index, it is necessary to group them. Each group is formed with five different terms, chosen randomly from the list of keywords. From that first group, one of the keywords is chosen to be the benchmark term of the groups that include the rest of the terms of the list. This process continues by selecting randomly four terms out of the list and joining them to the benchmark term, with the condition that none of them could be repeatable. In total, 19 groups are formed.

Following this procedure, in each given group j of searched terms, the frequency of the benchmark term $FI_{y,j}$ may differ from previous rounds because the highest search frequency in each new set of five searched terms, or fewer terms in the final round, automatically receives a maximum value of 100. The term $FI^{x}_{i,j,m}$ corresponds to the frequency of a word in a given group and month. For conformity of calculations, if in any group $FI^{x}_{i,j,m}$ was "<1" by assumption it was changed to 0.5.

Then, in a final step, the frequency $FI^{x,*}_{i,m}$of a word x which was used for building the index is calculated by using the formula:

(3) $$FI^{x,*}_{i,m} = FI^{x}_{i,j,m} \times \frac{FI^{*}_{y,m}}{FI_{y,j,m}}.$$

This approach "de-links" the frequency of each keyword i from the specific group that is searched with. The CCAI index is then obtained by summing the frequencies of the search as follows:

(4) $$CCAI_m = \sum_{i=1}^{i=77} FI^{x,*}_{i,m}.$$

This process was done three times with 3 different benchmark words in order to reinforce the results. For the first CCAI index the word "Environmental Impact" was chosen. For the second CCAI index the benchmark is "Greenhouse Effect". For the third CCAI index "Green Energy" was chosen as the benchmark. Once again, this choice was made randomly, but a crucial nuance for this analysis is that in neither case could the benchmark frequency be zero. If that were the case, it would compromise the analysis.

The graphic representation of the three Climate Change Awareness Indexes can be found below in Figures 1-3, as well as, the three main keywords that helped provoking certain spikes of the index. Overall, the most predominate words are Climate Change, Hurricane, Pollution, Floods, Global Warming, Storms and CO2.

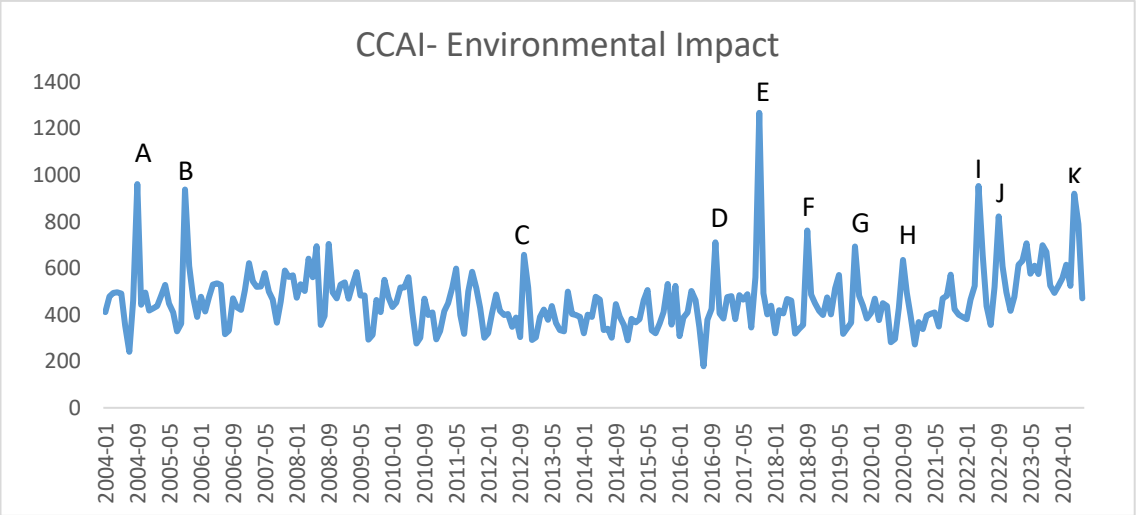

FIGURE 1 – Google Trends Climate Change Awareness Index with "Environmental Impact".

Figure 1 shows Google Trends Climate Change Awareness Index with "Environmental Impact" as the benchmark from January of 2004 until June of 2024. The top three words for each spike are the following: A- Hurricane, Flood and Pollution; B- Hurricane, Flood and Global Warming; C- Hurricane, Flood and Global Warming/CO2; D- Hurricane, Flood and CO2; E- Hurricane, Flood and Storms; F- Hurricane, Flood and CO2; G- Hurricane, Flood and Climate Change; H- Wildfire, Hurricane and Flood; I- Climate Change, Flood and Pollution/CO2; J- Hurricane, Flood and CO2; K- Climate Change, Flood and CO2.

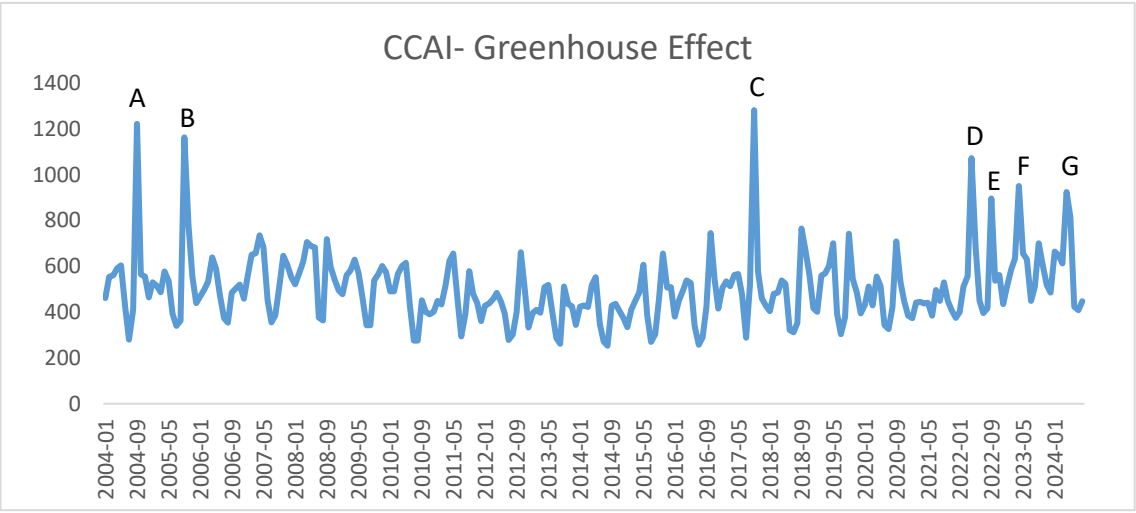

FIGURE 2 – Google Trends Climate Change Awareness Index with "Greenhouse Effect.

Figure 2 shows the Google Trends Climate Change Awareness Index with "Greenhouse Effect" as the benchmark from January of 2004 until June of 2024. To have the same range as the other indexes, from 0 to 1400, it was normalized by dividing by 10. The top three words for each spike are the following: A- Hurricane, Flood and Pollution; B- Hurricane, Flood and Global Warming; C- Hurricane, Flood and CO2; D- Climate Change, Flood and CO2; E- Hurricane, Flood and CO2; F- Climate Change, Flood and CO2; G- Climate Change, Flood and CO2.

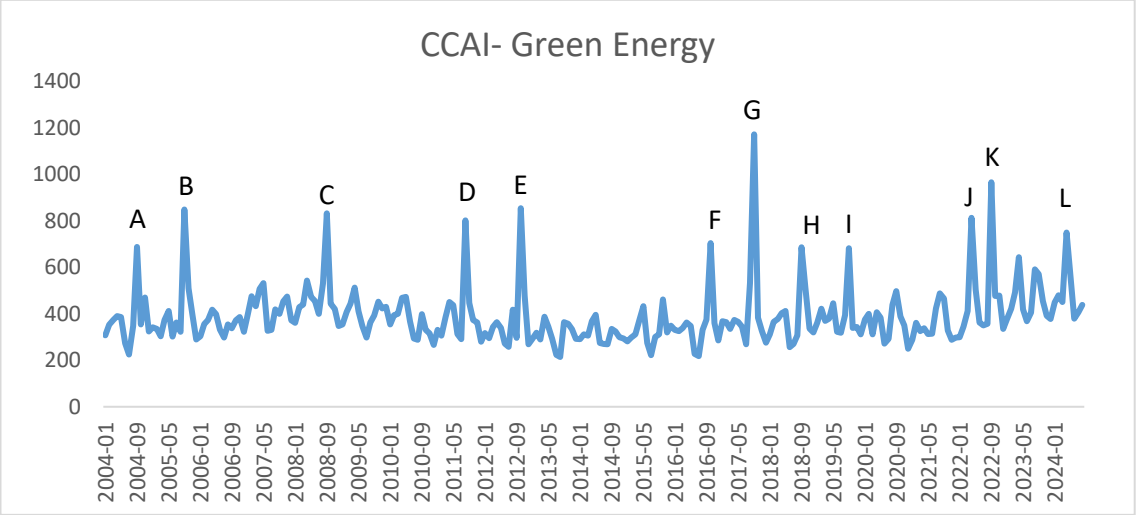

FIGURE 3 – Google Trends Climate Change Awareness Index with "Green Energy".

The figure 3 shows the Google Trends Climate Change Awareness Index with "Green Energy" as the benchmark from January of 2004 until June of 2024. The top three words for each spike are the following: A- Hurricane, Flood and Pollution; B- Hurricane, Flood and Pollution/ Global Warming; C- Hurricane, Flood and Global Warming; D- Hurricane, Flood and CO2; E- Hurricane, Flood and CO2: F- Hurricane, Flood and CO2; G- Hurricane, Flood and Climate Change; H- Hurricane, Flood and Climate Change; I- Hurricane, Flood and Climate Change; J- Climate Change, Flood and Pollution/CO2; K- Hurricane, Flood and CO2; L- Climate Change, Flood and CO2.

3.2. Analysis of the Impact

The second goal for this work is to study the impact of the Climate Change Awareness Index, CCAI, on 49 U.S. portfolio returns.

3.2.1. Data

3.2.1.1. Dependent Variable

In order to study the impact of the CCAI across all companies within an industry, the dependent variable Average Equal Weighted Returns (AEWR) of portfolios in the U.S. for 49 industries was chosen. By choosing AEWR, Small and Medium Enterprises (SMEs) are included with the same weight as larger companies. SMEs' returns are more sensitive to changes, which can be more vulnerable to climate-related risks (Serrasqueiro, Leitão and Smallbone, 2018).

Monthly industry portfolio returns from January 2004 until March 2024 was downloaded from Fama-French Data Library 1. Around 3815 firms are included. The industries considered are Agriculture; Food Products; Candy & Soda; Beer & Liquor; Tobacco Products; Recreation; Entertainment; Printing and Publishing; Consumer Goods; Apparel; Healthcare; Medical Equipment; Pharmaceutical Products; Chemicals; Rubber and Plastic Products; Textiles; Construction Materials; Construction; Steel Works; Fabricated Products; Machinery; Electrical Equipment; Automobiles and Trucks; Aircraft; Shipbuilding, Railroad Equipment; Defense; Precious Metals; Non-Metallic and Industrial Metal Mining; Coal Mining; Petroleum and Natural Gas; Utilities; Communications; Personal Services; Business Services; Computers; Computer Software; Electronic Equipment; Measuring and Control Equipment; Business Supplies; Shipping Containers; Transportation; Wholesale; Retail; Restaurants, Hotels, Motels; Banking; Insurance; Real Estate; Trading and Others. [2]

[1] Kenneth R. French - Data Library (dartmouth.edu)

[2] For each business segment included in each industry please find it here : https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/Data_Library/det_49_ind_port.html

3.2.1.2. Independent Variable

This section of the study aims to analyse the impact of CCAI on U.S. portfolios returns. The main focus of this work will be around the Climate Change Awareness Index with "Environmental Impact" as the benchmark. For the other indexes, the information can be found in the Appendix.

To ensure the robustness of the regression analysis, unit root tests were conducted, including the Augmented Dickey-Fuller (ADF) and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests, to assess the stationarity of the Climate Change Awareness Index. Non-stationary variables can lead to spurious regression results, making these tests essential for determining whether transformations are required to properly model the relationship between climate change and industry returns.

The ADF test was used to verify the presence of a unit root in the CCAI. The value of the ADF test was -3.1428 and the associated p-value was 0.09807. Since this p-value is greater than 0.05, we do not reject the null hypothesis that the series has a unit root, which suggests that the series is non-stationary at a significance level of 5%, but there is marginal evidence at 10%.

The KPSS test was also used, but with a null hypothesis opposite to the ADF test. The KPSS value was 0.46545, with a p-value of 0.04945. This means that, at a significance level of 5%, we reject the null hypothesis that the series is stationary. This result is in line with ADF test, suggesting that the series presents unit root and non-stationary.

In order to remove the unit root and transform it into a stationary series, a common approach is to take the first difference. For this reason we analyse the impact of the change in the CCAI, Δg_t on the portfolio returns, where g_t denotes the CCAI at time t (month t) and (5) $\Delta g_t = g_t - g_{t-1}$.

3.2.1.2. Control Variables

In order to control for the state of the economy and minimize selection bias, the following macroeconomic variables were included in the regression analysis: Unemployment Rate, Industrial Production and Federal Funds Effective Rate.
These variables were download from FRED - Federal Reserve Economic Data[3].

Unemployment Rate (UN)

The unemployment rate reflects the state of the country's labour market and economic activity since high unemployment is related to unstable or weak economic conditions. High unemployment levels lead to social problems such as poverty and social instability, but also to economic problems such as reduced disposable income and, consequently, reduced private consumption and investment. If not accompanied by an expansionary fiscal or monetary policy, this leads to a slowdown or reduction in economic growth. High unemployment affects consumer and investor expectations.
According to Pilinkus and Boguslauskas (2009) "most of the time unemployment rate, exchange rate and short-term interest rates negatively influence stock market prices". Stock returns often decline in periods of rising unemployment because investors expect lower future corporate profits and a risky economic environment does not attract risk-adverse investors.

By including the unemployment rate, it is possible to control variations in economic growth and employment trends, ensuring that the model captures the impact of the climate index more accurately. The objective of including this variable is to capture the direct impact of fluctuations in the absolute level of the unemployment rate on stock returns. For this reason the first difference is not used. In literature, using unemployment in levels to examine its direct macroeconomic implications without transforming it into a stationary form is a common practice. Gu (2023), among others, uses unemployment in its absolute level to analyse its impact on income inequality across different economic contexts.

[3] https://fred.stlouisfed.org/

Industrial Production (IP)

Industrial production also reflects the economic health and the level of demand for goods and services. When industrial production is high, it signals strong economic activity and potentially higher corporate profits, which can boost stock returns.

Some stock returns are sensitive to business cycles. For example, sectors such as manufacturing, materials and energy are more sensitive to fluctuations in industrial production. Including industrial production as a variable controls for cyclical effects and accounts for sector-specific sensitivities, leading to a more accurate assessment of how climate change impacts the stock market overall. According to Young (2006) "increased industrial production leads to increase in economic activity resulting in higher earnings for companies" so "potential higher earnings should result in an increase in stock valuations resulting in stock gains".

Omitting this variable can lead to biased estimates if changes in stock returns are driven by changes in economic output rather than climate change factors. By including industrial production as a control variable, it helps isolate the effect of the Climate Change Awareness Index on stock returns, ensuring that the observed relationship is not merely a reflection of underlying economic activity.

Industrial Production was measured and extracted as an index. To account for its nonlinear relationship with stock returns a logarithmic transformation was applied by taking log(IP) to ensure a more accurate model.

In this case, doing the logarithmic difference allows to capture economic trends, fluctuations and shocks more appropriately since it captures the percentage rate of change rather than the absolute value.

This is a common practice for stabilizing variance in financial and macroeconomic time series and for eliminating growth trends over time (Enders, 1995). For this reason, the dependent variable is:

$$(6) \qquad \Delta IP_{t-i} = \log IP_{t-i} - \log IP_{t-i-1}.$$

Federal Funds Effective Rate (FFR)

The federal funds effective rate is a key indicator of U.S. monetary policy. Changes affect the market sentiment, liquidity and risk appetite. Lower rates encourage contraction of loans and risk-taking, which increases stock returns, while higher rates have the opposite effect, restricting liquidity and reducing risk appetite.

The federal funds rate also affects the discount rates used to value stocks. Lower rates increase the present value of future cash flows, increasing stock return valuations. Ekanayake, Rance and Halkides (2008) studied the effects of federal funds target changes on stock prices and reached the conclusion that, on average, the impact on stocks of a decrease in federal funds target rate is positive, although when there is an increase in federal funds target rate the reaction on stocks is negative.

Including this rate in the regression model helps capture these effects, ensuring that the impact of the Climate Change Awareness Index on stock returns is not mistaken with changes in monetary policy.

Regarding robustness, federal funds effective rate showed stationarity, therefore, no adjustments were made.[4]

[4] The ADF test yielded a Dickey-Fuller statistic of -2.5996 with a p-value of 0.3234, failing to reject the null hypothesis of a unit root. The KPSS test shows that the KPSS level is 0.5068 with a p-value of 0.0403. This results suggest that the null hypothesis of stationarity fails to be rejected at 1%. KPSS test is considered more trustworthy than ADF, therefore FFR was used in its absolute value.

3.2.2. Regression Model

To analyse the potential impact that Climate Change Awareness Index (g) could have on portfolio returns (r) a multiple liner regression model is performed for each of the 49 industries during the periods of February 2004 until March 2024. The representation of the model is shown below:

$$r_{\{i,t\}} = \beta_0 + \beta_1 * \Delta g_t + \beta_2 * \Delta g_{t-1} + \delta IP_1 * 100\Delta IP_{t-1} + \delta IP_2 * 100\Delta IP_{t-2} + \delta IP_3 * 100\Delta IP_{t-3} + \delta IP_4 * 100\Delta IP_{t-4} + \delta UN_1 * UN_{t-1} + \delta UN_2 * UN_{t-2} + \delta UN_3 * UN_{t-3} + \delta UN_4 * UN_{t-4} + \delta FFR_1 * FFR_{t-1} + \delta FFR_2 * FFR_{t-2} + \delta FFR_3 * FFR_{t-3} + \delta FFR_4 * FFR_{t-4} + \varepsilon_{\{i,t\}}$$

Where i= 1, …, 49 and :

(5) $\Delta g_t = g_t - g_{t-1}$

(6) $\Delta IP_{t-i} = \log IP_{t-i} - \log IP_{t-i-1}$

To account for the state of the economy the control variables Industrial Production (IP), Unemployment Rate (UN) and Federal Funds Effective Rate (FFR) were included.

In addition, the four-lag model allows to capture the delayed effects of economic conditions and changes in monetary policy. For example, a change in the Federal Funds rate may take several months to impact the economy and the stock market fully. This improves the ability of the model to reflect the timing of macroeconomic variables impacting the portfolio returns.

4. Results and Discussion

The second main objective of this work is to study if there is an impact on portfolio returns of the change in the Climate Change Awareness Index. Table II presents the estimated coefficients (and their standard errors) from the multiple linear regression analysing the impact of changes in the Climate Change Awareness Index on the returns of 49 U.S. industries on February 2004 to March 2024.

TABLE II

CLIMATE CHANGE INDEX IMPACT ON PORTFOLIO RETURNS OF 49 U.S. INDUSTRIES

Industry	β_1	β_2	Industry	β_1	β_2
Agriculture	-0.00462 (0.00304)	-0.00388 (0.00261)	Defense	-0.00162 (0.00347)	-0.00346 (0.00381)
Food Products	-0.00325 (0.00201)	-0.00362** (0.00148)	Precious Metals	-0.00202 (0.00586)	-0.00674 (0.00560)
Candy & Soda	-0.00236 (0.00408)	-0.01003*** (0.00312)	Non-Metallic and Industrial Metal Mining	0.00220 (0.00420)	-0.00806** (0.00335)
Beer & Liquor	-0.00358* (0.00205)	-0.00536** (0.00210)	Coal Mining	-0.00194 (0.00595)	-0.00155 (0.00563)
Tobacco Products	-0.00071 (0.00280)	-0.00122 (0.00292)	Petroleum and Natural Gas	0.00218 (0.00468)	-0.00286 (0.00491)
Recreation	0.00035 (0.00330)	-0.00672** (0.00316)	Utilities	-0.00319* (0.00174)	-0.00237 (0.00164)
Entertainment	-0.00208 (0.00284)	-0.00747*** (0.00284)	Communications	-0.00160 (0.00274)	-0.00668** (0.00281)
Printing and Publishing	-0.00717* (0.00381)	-0.01056*** (0.00307)	Personal Services	-0.00364 (0.00303)	-0.00714*** (0.00277)
Consumer Goods	0.00066 (0.00260)	-0.00794*** (0.00281)	Business Services	-0.00247 (0.00278)	-0.00507** (0.00257)
Apparel	-0.00407 (0.00299)	-0.00703*** (0.00273)	Computers	-0.00325 (0.00323)	-0.00606** (0.00255)
Healthcare	-0.00347 (0.00291)	-0.00729*** (0.00254)	Computer Software	-0.00234 (0.00267)	-0.00495* (0.00282)
Medical Equipment	-0.00129 (0.00277)	-0.00716*** (0.00276)	Electronic Equipment	-0.00440 (0.00318)	-0.00689** (0.00300)

Industry	β_1	β_2	Industry	β_1	β_2
Pharmaceutical Products	-0.00247 (0.00387)	-0.00763** (0.00320)	Measuring and Control Equipment	-0.00373 (0.00292)	-0.00540* (0.00309)
Chemicals	-0.00232 (0.00317)	-0.00358 (0.00316)	Business Supplies	-0.00239 (0.00325)	-0.00629** (0.00271)
Rubber and Plastic Products	-0.00092 (0.00325)	-0.00497* (0.00297)	Shipping Containers	-0.00169 (0.00258)	-0.00517* (0.00271)
Textiles	-0.00261 (0.00353)	-0.00631 (0.00402)	Transportation	-0.00419 (0.00378)	-0.00519** (0.00257)
Construction Materials	-0.00199 (0.00308)	-0.00686** (0.00280)	Wholesale	-0.00270 (0.00285)	-0.00518** (0.00254)
Construction	-0.00239 (0.00343)	-0.00543 (0.00350)	Retail	-0.00107 (0.00303)	-0.00798*** (0.00277)
Steel Works Etc	-0.00195 (0.00410)	-0.00653* (0.00383)	Restaurants, Hotels, Motels	-0.00142 (0.00244)	-0.00711*** (0.00256)
Fabricated Products	0.00062 (0.00360)	-0.00581 (0.00368)	Banking	-0.00334 (0.00245)	-0.00379* (0.00209)
Machinery	-0.00247 (0.00342)	-0.00445 (0.00317)	Insurance	-0.00307 (0.00222)	-0.00413** (0.00206)
Electrical Equipment	-0.00415 (0.00324)	-0.00773** (0.00360)	Real Estate	-0.00023 (0.00330)	-0.00293 (0.00297)
Automobiles and Trucks	-0.00539 (0.00406)	-0.00783** (0.00363)	Trading	-0.00163 (0.00303)	-0.00482* (0.00248)
Aircraft	-0.00462 (0.00323)	-0.00881** (0.00419)	Others	-0.00076 (0.00218)	-0.00432* (0.00227)
Shipbuilding, Railroad Equipment	-0.00131 (0.00395)	-0.00537 (0.00341)			

The coefficient β_1 represents the effect of the variation of the index between the current period ($g_t - g_{t-1}$). The coefficient β_2 captures the effect of the change in the growth rate of the index in the previous period ($g_{t-1} - g_{t-2}$). Heteroskedasticity and Autocorrelation-Consistent (HAC) standard errors are calculated using the Newey-West method with a Bartlett kernel and bandwidth of $T^{1/3}$ and reported in parentheses. Statistical significance levels are indicated as *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. A two-tailed test was used.

The Climate Change Awareness Index used is the first one with “Environmental Impact” as the benchmark, as it provided more industries with statistical evidence. The results with the others CCAI can be found in the Appendix.

A general analysis of the Table II allows to observe that all coefficients are small but there is a consisted negative relationship. For coefficients that showed statistical evidence, the impact of the change in CCAI was negative, ranging between -0.0156 and -0.0032. $\beta_1$and β_2 correspond to the coefficient of variation of the CCAI (Δg_t). When there is an increase in awareness, Δg_t has a positive value. Since the coefficients are negative, an increase in awareness provokes a decrease in returns. In contrast, when there is a decrease in awareness, the variation is negative. Adding to the fact that the coefficients are negative, the decrease of awareness leads to a positive return. Different levels of statistical significance can be found in multiple industries but in general, the statistical significance is found in coefficient β_2, meaning, there is a delayed effect in the industries results.

The results indicate that changes in the CCAI are statistically significant for a total of 36 industries. Among them, only 3 industries showed statically evidence for β_1 , being one “Utilities” and the other two by having both coefficients statistically significant “Beer & Liquor” and “Printing and Publishing”.

At a 10% level, 9 industries showed statistical evidence for β_2, these are: “Rubber and Plastic Products", “Steel Works”, “Computer Software”, “Measuring and Control Equipment”, “Shipping Containers, “Banking”, “Trading” and “Others”.

At a 5% level, the results indicate that 15 industries are negatively impacted by changes in CCAI at lag 2 (corresponding to the β_2 coefficient). These are: “Food Products”, “Recreation”, “Pharmaceutical Products”, “Construction Materials”, “Electrical Equipment”, “Automobiles and Trucks”, “Aircraft”, “Non-Metallic and Industrial Metal Mining”, “Communications”, “Business Services”, “Computers”, “Electronic Equipment”, “Business Supplies”, “Transportation”, “Wholesale” and “Insurance”.

With the highest level of statistical evidence, at a 1% level, 9 industries showed to be impacted, these being “Candy & Soda”, “Entertainment”, “Consumer Goods”, “Apparel”, “Healthcare”, “Medical Equipment”, “Personal Services”, “Retail” and “Restaurants, Hotels, Motels”.

From these industries, those that showed to be less influenced are “Banking”, “Trading” and surprisingly “Insurance” and “Food Products”. The ones that showed to be more impacted are “Retail”, “Non-Metallic and Industrial Metal Mining”, “Aircraft”, “Candy & Soda” and the most impacted of all “Printing and Publishing”.

The results from the Table II show no statistical evidence for “Agriculture”, “Tobacco Products”, “Chemicals”, “Textiles”, “Construction”, “Fabricated Products”, “Machinery”, “Shipbuilding and Railroad Equipment”, “Defense”, “Precious Metals”, “Petroleum and Natural Gas”, “Coal Mining” and “Real Estate”.

Shipbuilding & Railroad Equipment and Defense (including guided missiles and tanks) have no statistical evidence in any level. These industries are characterized as a non-consumer market, in this case the consumer is mostly the government. For this reason, these industries are less sensitive to economic and environmental changes. With the main goal of creating or improving large scale transportation infrastructures and strengthen national defense, although they are facing pressure to decarbonize, climate change concerns and environmental sustainability are far away from being a priority (Dimitrova et al., 2021). In addition, analysing climate change uncertainty in the short run has no impact on these industries since they normally involve projects with large investments and long term deadlines.

Tobacco production is a target of environmental regulations and environmental taxation but tobacco consumption is inelastic and it is not much influenced by economic and environmental changes. Tobacco companies' returns are more influenced by factors like health regulations and taxation, with focus on health and social impacts, rather than changes in climate change awareness (DeCicca, Kenkel and Lovenheim, 2022).

Regarding Real Estate, although certain regions may face environmental risks such as rising sea levels and extreme weather, others remain stable, making it difficult to detect a uniform effect on real estate portfolios.

According to the United Nations Environment Programme Finance Initiative (UNEP IF) report “Climate Risk in the Real Estate Sector”, this industry is facing an increase in regulation and policy pressure regarding disclosure of climate risks, stricter building standards and carbon pricing as well as shifts in market preferences, towards high-efficiency building with renewable energy sources. However, real estate is viewed as a long-term investment, therefore immediate climate concerns may not drastically impact short-term returns. Additionally, according UNEP IF report “Climate Risk & Commercial Property Values”, historically property prices decrease after extreme climate events but short and momentaneous in areas where this events are frequent, meaning the climate risk is already capitalized into pricing and property values. This can also explain why in the immediate there is no statistical evidence.

Regarding the Precious Metals industry including gold, silver and other precious metals although they are a natural resource, they also are often viewed as a safe asset during economic or geopolitical crises (Baur and Smales, 2020), meaning that these precious metal stocks may not respond significantly to climate-related crises or increase in awareness.

The Coal Mining industry is directly linked to carbon emissions and theoretically, it should be highly sensitive to climate change concerns. However, coal still remains a critical energy source in some parts of the world and despite increase in climate change awareness coal will continue to be consumed in many regions. Also, the negative environmental impact of coal could be already taken into account in the coal stocks price as it negative impact on the environment has been well known for decades (Arampatzidis et al., 2021). This can also explain why there is no evidence for this industry but for Non-Metallic and Industrial Metal Mining is. The fact that is not known for decades makes it more vulnerable to immediate changes in environmental policies and changes in demand for alternative materials or sustainable practices causing a measurable and negative financial impact.

Non-significance for Tobacco Products, Shipbuilding and Railroad Equipment, Real Estate and Defense was expected but the non-significance for Agriculture, Construction, Textile and Petroleum and Natural Gas was a surprise.

However, a pattern can be seen. Agriculture and Construction do not have statistical evidence but Food Products and Construction Material have at 5% level, as well as Textile does not but Apparel has at 1%.

These results can be explained by direct contact with customers. Climate change awareness directly impacts consumer preferences, driving consumers to prioritize organic, locally sourced or eco-friendly products. And it's possible to express it better when buying clothes and not when the fibre is being made. In the majority Agriculture, Construction and Textile are a B2B industry and are further removed from direct consumer interaction, experience less immediate pressure from differences in preferences from climate-conscious behaviour. In contrast, although is not so distinct in its majority for Construction Materials but for Food Products and Apparel these industries are a B2C having direct pressure from costumers that seek sustainable materials, ethical labour practices and sustainability certifications. This also explains why Wholesalers are statistical significant at 5% and Retail and Consumer Goods are statistically significant at 1%. As moving to further downstream industries, there is more visibility in these industries creating immediate market pressure for companies to adopt sustainable practices industries that further upstream industries like Agriculture, Construction and Textile may not experience this same direct consumer pressure since their products are not as visible to end-users (Schmidt et al., 2016).

Companies that adopt sustainable practices, can be lead to higher initial operational costs, as for example searching suppliers with eco-friendly farming methods and production methods and seeking alternatives to reduce waste, which may impact profitability and consequently stock returns. Companies that fail to adapt, risk negative consumer sentiment, which may directly affect their sales, having impact on the stocks performance.

When mentioning climate change, fossil fuels are always a topic of focus. The non-significance of Petroleum and Natural Gas was a surprise since is directly involved in the production of fossil fuels.

It would be expected to have a statistical impact and this to be negative. Although there is non-significance and β_2 is negative, interestingly enough, β_1 is actually positive, with 0.00218, so there is not a clear path of the potential influence.

This aligns with the literature. In the U.S., El Ouadghiri et al. (2022) investigated investor attention to the fossil fuel divestment movement (FFD) and the impact on stock returns of companies involved in fossil fuel extraction from 2012 until 2020. To measure investor attention to the FFD movement, the author used 3 tools including Google's weekly Search Volume Index on the topic “divestment from fossil fuels” and reported a positive relationship between investor attention to FFD and excess returns of shares of american companies related to fossil fuels. Therefore, contrary to what was initially expected, the "stigmatization of the fossil fuel industry does not reduce the stock returns of fossil fuel-related companies”. Despite changes in climate change awareness, the global dependency on fossil fuels for energy, manufacturing, transportation and so much more limits the immediate impact on the financial returns of this sector.

Automobiles, Trucks, Aircraft and Transportation are more exposed to consumer and regulatory pressures driven by climate change awareness. Increasing demand for fuel efficient vehicles, electric cars, sustainable transportation solutions and overall the technological advancements in low-carbon alternatives directly impacts these industries. Moreover, climate-related regulations and technological shifts (such as emissions standards) affect production costs, design and market demand, making the relationship between climate change awareness and returns statistically significant for these sectors (Carlin and Arshad, 2024).

Regarding the lack of evidence for Fabricated Products and Machinery, these are considered intermediary industries and they serve a broad range of industries. The returns depend on the health of the final industries and it’s not directly affected by changes in climate change awareness. These industries also showed short-run resilience to changes in climate change, mainly due to inelastic and stable demand since they operate in long term contracts and projects. The same reasoning can be applied to Chemicals.

Including plastics and synthetic resins, rubbers and paints, these enter into numerous different products and services across many different industries. The Chemical industry’s exposure to climate change tends to be more indirect. While there is growing awareness of the environmental impact of plastics and chemicals, changes in demand for more sustainable alternatives are more gradual, with less immediate impact on returns.

It requires long-term adaptation to environmental regulations and investment in cleaner technologies and innovations such as bio-based chemicals.

The industry "Utilities" is the only case where β_1 is statistically evidence and not β_2. With a 10% significance this suggest an immediate sensitivity to changes in climate change awareness, negatively affecting its returns. Inside this category are included industries of Electric, Gas & Sanitary services, Irrigation systems and others. Policies to save water, electricity and policies aiming the reduction of greenhouse gases emissions contribute to changes in climate change awareness. The decrease in demand can have immediate negative impact in stock returns of Utilities. Associated with water scarcity and efficiency, companies producing irrigation systems are under pressure to develop more water-efficient technologies, as technological improvements have not yet bring full benefits through water efficiency (Levidow et al., 2014). Innovation costs and adaptation to stricter water use regulations may negatively affect profitability. The lack of significance in β_2 shows no further impact from previous changes in awareness suggesting a fast adjustment in utility stock prices when there is new changes and less persistence in the market's reaction over time.

For industries Rubber and Plastic Products, Steel Works, Computer Software, Measuring and Control Equipment, Shipping Containers, Banking and Trading showed a statistical significance, of the impact of climate change awareness on returns, at 10% level for β_2. However, for the other GTU indexes these industries have no statistical evidence, which indicates a weaker significance. Nonetheless, it is worth mentioning the industries Rubber and Plastic Products and Banking. The harmful effects of plastic pollution and the carbon-intensive processes involved in manufacturing forces this industry to transition to more sustainable materials, such as biodegradable plastics or recycled rubber. Climate change awareness has also led consumers to reduce their plastic consumption. The decrease in demand and higher costs of innovation can negatively affect their profit margins, leading to a negative impact on returns.

Regarding Banking, the loan portfolio can be affected if they finance companies in industries vulnerable to physical and transition risk. Due to extreme weather or long-term climate changes, physical risks affect banks' operations and clients, impacting creditworthiness and asset values.

Transition risks arise from the shift to a low-carbon economy, including funding carbon-intensive companies, involving stakeholder demands and regulatory changes (Sutcliffe, 2021). Overall, the increase of climate change awareness changes the risk assessments and in consequence interest rates and lending criteria are adjusted. These shifts could impact profitability and stock returns. Even though this impact is negative in the short-run, banks can benefit from new opportunities in green finance, for example financing renewable energy projects, which can improve their profitability over time.

The results show that medical related industries such as Healthcare, Medical Equipment and Pharmaceutical seem to be affected in the short-run by the impact of changes in climate change awareness on returns at 5%, 5% and 1% level respectively. Strict environmental regulations and adaptations that these industries have to make regarding their practices and supply chains, as for example seeking suppliers that meet strict environmental standards or in closer locations to reduce transportation emissions, can lead to increased operational costs and affect logistical efficiency and may affect the financial performance of these industries in the short-run. However, in the long-run, the increasing cases of climate-related diseases or the appearance of climate-related health crises, can boost the development of new treatments or medical devices related to climate-induced health problems and drive these industries to profits, which may impact positively medical related stocks returns.

Superfluous or non-essential goods, activities and services are also influenced. Entertainment (including professional sports and amusement and recreation services) and Personal Services (including laundry and cleaning services, refrigeration, truck & auto rental and leasing) are significant at 1% level. Candy & Soda (including bottled-canned soft drinks), Restaurants, Hotels and Motels (including fast food chains), Communications (including radio & television broadcasters), Recreation, (including fishing, hunting & trapping,and plastic toys) are significant at 5% level.

As climate change awareness grows, consumer are more conscious about their role when buying and engaging in certain activities, more health and environmental conscious. The Candy & Soda industry is seen as unsustainable due to high sugar levels, unsustainable packaging and wasteful and energy intensive manufacturing process.

Industries that are associated with traveling such as Entertainment, Hotels and Motels may see reduced consumer spending as environmentally-conscious individuals opt for greener activities or choose to stay local. With the rising concerns about species extinction and environmental damage, governments impose stricter regulations on hunting and fishing quotas, seasons and zones. These may lead to a decrease in supply and tourism of this activities and therefore profits. There is also pressure for this industries to adopt more sustainable practices such as energy-efficient consumption, waste reduction practices, reduction of transportation emissions and in some cases sustainable sourcing of food and products. These adjustments can be costly and cut into profit margins, negatively impacting returns.

Insurance is significant at 5% level. CCAI follows the pattern of some extreme weather events. For example, in Figure 1-3, peak A corresponding to September of 2004, two hurricanes hit the U.S., hurricanes Ivan and Jeanne. Peak I in September of 2022 with hurricane Ian (peaks E and K for the others CCAI). The occurrence of this natural disasters have a negative direct impact on insurance companies, since it increases the likelihood and costs of claims for insurers. As extreme climate events become more frequent and the awareness of climate change grows, this industry is forced to adjust their models and policies to account for these risks. In the city Austin where there is a high risk of flooding, insurance policies for many homes were adjusted, rising premiums by 16% in the first semester of 2023 alone (Adeel, 2023). Also, long-term risks exposure that influence business operations, health or the valuation of properties due to sea-level rise, soil erosions and others, force this need for adjustment. This has become a big problem for this industry as dozens of companies are leaving the market. Farmers Insurance was one of them and they told BBC “This business decision was necessary to effectively manage risk exposure" (Sherriff, 2024). Moreover, there is an increase in regulatory pressure and also investors pressure for insurance companies to assess and disclose these risks. This can force changes in investments strategies. Insurers are some of the world’s largest institutional investors and they are pressured to reduce their investments in carbon-intensive industries and shift towards greener and more sustainable assets.

Business Services (including industrial launderers and personnel supply services) and Business Supplies (including paper and allied products, pens, pencils & other artists’ supplies) are influenced at a 5% level.

Climate change awareness has increased the focus on water conservation and energy efficiency. Paper and allied products industries are associated with deforestation and high carbon footprint. Regulatory changes, shifts toward sustainable practices or creation of eco-friendly versions, can increase operational and innovation costs and therefore affect negatively these industries returns.

Computer, Electronic Equipment and Electrical Equipment industries have statistical significance on β2 of 5%. The reasons why these three industries do not have statistical significance on β1, meaning that climate change awareness does not impact them immediately, may be that the impact of environmental regulations and global supply chain dynamics, as many of these companies source components from various regions around the world with less environmental policies, often take time to have influence on the financial performance of these industries. However, regarding the statistical significance shown, it may be justified by higher costs that these companies face in order to comply with regulatory policies and changes in the supply chains. This factors may create a delayed impact on stock returns of companies related with this industries.

The Beer & Liquor and Printing and Publishing industries shows a statistically significant result for β_1, which means that stock returns for both sectors are sensitive to immediate changes in the Climate Change Awareness Index.

For Beer & Liquor, this can be linked to the growing awareness around the environmental impact of alcohol production. This industry is known to be resource and energy-intensive process, causing significant environmental degradation especially concerning water use, energy use, carbon emissions, pollution of soils and waterways, agricultural inputs and packaging waste (Cook et al., 2024). Investors may anticipate increased costs or changes in consumer preferences toward more sustainable practices, which would directly affect the industry's returns.

The even stronger statistical significance of β_2 shows persistent and more evident impact on stock returns. This reflects how the industry faces a more extended reaction from both regulatory bodies and consumers. For instance, shifts toward organic or environmentally friendly products takes time to materialize in consumer behaviour and industry operations.

In the book “Toward a Sustainable Wine Industry”, regarding efficient ways to manage and reduce consumption of materials, the author states “in some cases (glass bottles or corks), it is difficult to reduce the number of units consumed without substantially affecting the firms’ economic profitability”. The increased costs related to innovation, new ways of production, new recycling programs, waste management, carbon tax and more can lead to a reduction of this industries returns, explaining the significant lagged impact.

For Printing and Publishing with a 5% significance for β_1 and 1% significance for of β_2, it shows an immediate and prolonged negative impact. As environment concern grows, this industry is seen as environmentally harmful.

According to 2023 data from the literary industry research group WordsRated[5], for the U.S. alone, the publishing industry kills around 32 million trees in order to produce books in a single year and globally emits more than 40 million metric tons of CO2. Printing and Publishing is resource intensive industry directly associated with deforestation, chemical pollution from inks and CO2 emissions. Many practices such as recycling books, second hand markets and most importantly digital solutions are sustainable practices that are changing consumer preferences and affecting negatively this industry’s stock returns.

[5] https://wordsrated.com/impact-of-book-publishing-on-environment/

5. CONCLUSION

In conclusion, this research aimed to construct an index that reflected changes in climate change awareness and later on studied how this index can affect portfolios returns in the U.S. for the last 20 years.

The results show a statistically significant impact on the returns of 36 industries and its impact is negative. This indicates that as concerns increase, returns are expected to decrease.

Overall, industries that showed non-significance in changes of climate change awareness have some characteristics in common. These are industries with less contact with the final costumer due to less visibility, industries with inelastic demand, industries that involve long-term investments or are non-consumer industries. The lack of statistical significance of the change in CCAI on portfolio returns is mainly due to the fact that they are being protected by from market risks and reputational risks, such as shift in consumers' preferences, reduced demand, increase in raw materials and stigmatization of the sector.

Industries with superfluous or non-essential goods, as well as leisure activities and services, downstream industries and industries with direct contact to the consumer were those for which the change in CCAI was statistically significant.

The statistically significant results of the impact of CCAI on the portfolio returns can be explain as follows. As the concern regarding climate change has grown, political and legal changes have been more predominant. The increase in climate-related regulations, emissions reporting, pricing GHG emissions and carbon tax as well the need to comply and obtain sustainability certifications can increase operational costs and its non-compliance can be heavily penalized.

In addition, there is pressure to create and move to technological alternatives that are low in carbon, that are water and energy efficient. These technological advances can increase costs of investment and R&D.

Downstream industries with more visibility to end-consumers are also more vulnerable to market risks. Such as changes in risk assessment and changes in supply chains, as they are pressured and aim to become more sustainable, to reduce waste, transportation, to find more eco-friendly suppliers and components can lead to an increase in raw materials costs, operational costs and inefficiencies in the supply chain. This also leads to shifts in demand and supply of certain products and services.

In line with market risks, there is greater vulnerability to consumer behaviour and reputational changes. Shifts in consumer preferences, the increase in costumer pressure for sustainable materials, eco-friendly products and ways of production, sustainability certifications as well the stigmatization of sector (especially if linked with pollution, GHG emissions, deforestation, etc.) can reduce demand and increase operational and market costs.

These emergent and growing vulnerabilities are very important factor as they impact portfolio returns. Therefore, investors should account for the changes in Climate Change Awareness and its possible consequences in the decision-making process.

This dissertation contributes to the growing literature that uses Google Trends to create indexes. Based on the assumption that Internet users search for information online when they are uncertain or interested and with a collection of Climate Change related keywords, the Climate Change Awareness Index, CCAI, has been built for the U.S. based on data from the last 20 years.

Furthermore, this dissertation contributes to the growing literature about the impact of climate change on stock returns. This is the first work that studies the impact climate change awareness on 49 U.S. industries portfolios.

Finally, this dissertation provides a new insight into the relationship between a new Google Trends Index and portfolio returns in the U.S.

Future research could exploit the impact of CCAI in green portfolios and the use of CCAI to forecast portfolio returns.

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APPENDICES

TABLE III

ADF, PP AND KPSS TEST FOR UNIT ROOT

Industry	ADF	PP	KPSS
Industrial Production *1º Logarithmic difference*	-5.5804** (0.01)	-12.791 (0.0012)	0.043691** (0.01)
Unemployment Rate	-2.1941 (0.4941)	-2.6123 (< 2.2e-16)	0.90478** (0.01)
Federal Funds Effective Rate	-2.5996 (0.3234)	-0.681 (< 2.2e-16)	0.5068** (0.04013)
Climate Change Index	-3.1428* (0.09807)	-10.8544 (3.546e-7)	0.46545** (0.04945)

In Table 3 is presented the unit root tests with Dickey-Fuller value, Z-tau value, KKPS value and the respective p-values in brackets, for each variable.

Statistical significance levels are indicated as *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. For ADF and PP, H_0 = Variable has a unit root and H_0 = Variable is stationary for KPSS test.

TABLE IV

IMPACT OF CLIMATE CHANGE AWARENESS INDEX ON PORTFOLIO RETURNS OF 49 U.S. INDUSTRIES- BENCHMARK: "GREENHOUSE EFFECT"

Industry	β_1	β_2	Industry	β_1	β_2
Agriculture	-0.00037 (0.00027)	-0.00024 (0.00024)	Defense	-0.00032 (0.00032)	-0.00033 (0.00035)
Food Products	-0.00031* (0.00018)	-0.00022* (0.00012)	Precious Metals	0.00001 (0.00049)	-0.00059 (0.00045)
Candy & Soda	-0.00035** (0.00031)	-0.00067** (0.00028)	Non-Metallic and Industrial Metal Mining	0.00013 (0.00037)	-0.00054* (0.00029)
Beer & Liquor	-0.00040 (0.00019)	-0.00037** (0.00016)	Coal Mining	0.00007 (0.00048)	-0.00028 (0.00050)
Tobacco Products	-0.00002 (0.00026)	-0.00020 (0.00023)	Petroleum and Natural Gas	0.00013 (0.00042)	-0.00022 (0.00046)
Recreation	-0.00023 (0.00028)	-0.00058** (0.00025)	Utilities	-0.00027 (0.00017)	-0.00010 (0.00014)
Entertainment	-0.00021 (0.00026)	-0.00052** (0.00025)	Communications	-0.00026 (0.00026)	-0.00049** (0.00025)
Printing and Publishing	-0.00051* (0.00030)	-0.00075*** (0.00027)	Personal Services	-0.00027 (0.00025)	-0.00047* (0.00025)
Consumer Goods	-0.00001 (0.00023)	-0.00064*** (0.00024)	Business Services	-0.00025 (0.00025)	-0.00036 (0.00022)
Apparel	-0.00038 (0.00025)	-0.00056** (0.00023)	Computers	-0.00032 (0.00029)	-0.00045** (0.00022)
Healthcare	-0.00033 (0.00024)	-0.00063*** (0.00022)	Computer Software	-0.00028 (0.00024)	-0.00033 (0.00024)
Medical Equipment	-0.00020 (0.00023)	-0.00062*** (0.00024)	Electronic Equipment	-0.00045 (0.00030)	-0.00042 (0.00028)
Pharmaceutical Products	-0.00016 (0.00031)	-0.00059* (0.00028)	Measuring and Control Equipment	-0.00039 (0.00025)	-0.00038 (0.00025)

Industry	β_1	β_2	Industry	β_1	β_2
Chemicals	-0.00025 (0.00028)	-0.00018 (0.00026)	Business Supplies	-0.00023 (0.00028)	-0.00044* (0.00024)
Rubber and Plastic Products	-0.00021 (0.00030)	-0.00035 (0.00026)	Shipping Containers	-0.00015 (0.00022)	-0.00035 (0.00022)
Textiles	-0.00022 (0.00030)	-0.00047 (0.00034)	Transportation	-0.00036 (0.00030)	-0.00036 (0.00023)
Construction Materials	-0.00020 (0.00027)	-0.00055** (0.00026)	Wholesale	-0.00027 (0.00025)	-0.00039* (0.00023)
Construction	-0.00022 (0.00030)	-0.00033 (0.00032)	Retail	-0.00024 (0.00027)	-0.00052** (0.00026)
Steel Works Etc	-0.00026 (0.00036)	-0.00049 (0.00034)	Restaurants, Hotels, Motels	-0.00015 (0.00021)	-0.00049** (0.00024)
Fabricated Products	-0.00005 (0.00029)	-0.00054* (0.00032)	Banking	-0.00030 (0.00020)	-0.00020 (0.00019)
Machinery	-0.00028 (0.00030)	-0.00033 (0.00028)	Insurance	-0.00026 (0.00020)	-0.00019 (0.00018)
Electrical Equipment	-0.00048* (0.00029)	-0.00057* (0.00030)	Real Estate	-0.00020 (0.00026)	-0.00016 (0.00024)
Automobiles and Trucks	-0.00054 (0.00034)	-0.00054 (0.00033)	Trading	-0.00017 (0.00026)	-0.00027 (0.00021)
Aircraft	-0.00038 (0.00027)	-0.00074** (0.00036)	Others	-0.00001 (0.00019)	-0.00032* (0.00019)
Shipbuilding, Railroad Equipment	-0.00016 (0.00034)	-0.00038 (0.00030)			

TABLE V

IMPACT OF CLIMATE CHANGE AWARENESS INDEX ON PORTFOLIO RETURNS OF 49 U.S. INDUSTRIES- BENCHMARK: "GREEN ENERGY"

Industry	β_1	β_2	Industry	β_1	β_2
Agriculture	-0.00346 (0.00343)	-0.00453 (0.00407)	Defense	-0.00222 (0.00390)	-0.00271 (0.00388)
Food Products	-0.00296 (0.00249)	-0.00259 (0.00197)	Precious Metals	0.00028 (0.00493)	-0.00993* (0.00501)
Candy & Soda	-0.00156 (0.00430)	-0.00613* (0.00344)	Non-Metallic and Industrial Metal Mining	-0.00027 (0.00470)	-0.01010* (0.00517)
Beer & Liquor	-0.00324 (0.00256)	-0.00499** (0.00242)	Coal Mining	0.00066 (0.00646)	-0.00496 (0.00726)
Tobacco Products	0.00062 (0.00335)	-0.00023 (0.00305)	Petroleum and Natural Gas	0.00086 (0.00517)	-0.00340 (0.00585)
Recreation	-0.00095 (0.00387)	-0.00729** (0.00356)	Utilities	-0.00268 (0.00213)	-0.00335** (0.00161)
Entertainment	-0.00171 (0.00351)	-0.00723** (0.00310)	Communications	-0.00216 (0.00348)	-0.00610* (0.00334)
Printing and Publishing	-0.00474 (0.00415)	-0.00902*** (0.00310)	Personal Services	-0.00331 (0.00340)	-0.00712** (0.00319)
Consumer Goods	0.00070 (0.00341)	-0.00680** (0.00312)	Business Services	-0.00266 (0.00318)	-0.00533* (0.00305)
Apparel	-0.00323 (0.00363)	-0.00664** (0.00318)	Computers	-0.00448 (0.00376)	-0.00624** (0.00303)
Healthcare	-0.00370 (0.00309)	-0.00754** (0.00299)	Computer Software	-0.00311 (0.00301)	-0.00541 (0.00333)
Medical Equipment	-0.00140 (0.00299)	-0.00620** (0.00288)	Electronic Equipment	-0.00535 (0.00349)	-0.00666** (0.00332)
Pharmaceutical Products	-0.00312 (0.00407)	-0.00736** (0.00373)	Measuring and Control Equipment	-0.00356 (0.00302)	-0.00573 (0.00352)

Industry	β_1	β_2	Industry	β_1	β_2
Chemicals	-0.00293 (0.00347)	-0.00467 (0.00427)	Business Supplies	-0.00181 (0.00393)	-0.00578* (0.00328)
Rubber and Plastic Products	-0.00025 (0.00383)	-0.00507 (0.00363)	Shipping Containers	-0.00010 (0.00279)	-0.00541 (0.00335)
Textiles	-0.00088 (0.00380)	-0.00581 (0.00410)	Transportation	-0.00341 (0.00381)	-0.00548 (0.00338)
Construction Materials	-0.00143 (0.00340)	-0.00756** (0.00369)	Wholesale	-0.00285 (0.00333)	-0.00588* (0.00322)
Construction	-0.00285 (0.00398)	-0.00640 (0.00460)	Retail	-0.00148 (0.00385)	-0.00669** (0.00339)
Steel Works Etc	-0.00370 (0.00462)	-0.00754 (0.00478)	Restaurants, Hotels, Motels	-0.00072 (0.00322)	-0.00566* (0.00293)
Fabricated Products	-0.00047 (0.00387)	-0.00655 (0.00436)	Banking	-0.00231 (0.00253)	-0.00294 (0.00247)
Machinery	-0.00259 (0.00374)	-0.00507 (0.00421)	Insurance	-0.00266 (0.00256)	-0.00333 (0.00238)
Electrical Equipment	-0.00498* (0.00334)	-0.00850** (0.00405)	Real Estate	-0.00062 (0.00381)	-0.00233 (0.00379)
Automobiles and Trucks	-0.00505 (0.00458)	-0.00785* (0.00462)	Trading	-0.00200 (0.00348)	-0.00465 (0.00303)
Aircraft	-0.00400 (0.00325)	-0.00704* (0.00384)	Others	0.00044 (0.00237)	-0.00489* (0.00279)
Shipbuilding, Railroad Equipment	-0.00181 (0.00457)	-0.00918 (0.00623)			